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EFFECTS OF LIMING ON CHANGES IN PSEUDOGLEY AGROCHEMICAL PROPERTIES AND ALFALFA YIELD

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The paper examines the effects of lime application at the rate of 3 t/ha on pseudogley soil agrochemical changes and alfalfa yield during a two-year period.

The applied lime in combination with mineral fertilizers significantly decreased acidity in H_2O (by 0.6 pH units) and in nKCl (by 0.81 pH units). At the same time, there was increase in phosphorus availability (from 6.2 mg/100g of soil, control, to 19.1 mg/100 g of soil, variant with lime) and soil base saturation percentage in the 0-30 cm arable horizon. The performed liming intensified organic matter

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mineralization, which caused decrease of humus content as well as of mobile Al and Fe content compared to control.

Moderate liming improved pseudogley agrochemical properties, which was manifested by increased alfalfa yield. In the first study year 19.7 t/ha of forage and 5.7 t/ of hay, respectively, was produced in control variant, while 28.5 t/ha of forage and 8.2 t/ha of hay, respectively, was produced in a variant with liming. Even higher yield was achieved in the second year of alfalfa utilization (8.5 t/ha of forage and 2.2 t/ha of hay, respectively, was produced in control, and 71 t/ha of forage and 16.3 t/ha of hay, respectively, in a variant with liming).

*Key words***:** liming, agrochemical properties, pseudogley, alfalfa, yield.

INTRODUCTION

Soil acidity is one of the factors limiting to a high extent the development of many grown crops (VON UEXKULL and MUTERT, 1995).

In the Republic of Serbia soils of light acid, acid and extremely acid reaction are widely distributed, accounting for approx. 60% of total arable land (STEVANOVIĆ et al., 1995).

In Serbia pseudogely soils cover approx. 500,000 ha. They are characterized by very marked acidity. Alfalfa is one of the crops most susceptible to soil acidity (Hauptvogel, 2003). The most suitable soils for alfalfa growing are considered to be those of neutral to weakly alkaline reaction, with pH ranging from 6.6–7.5 (LANYON and GRIFFITH, 1988; RENGEL, 2002; BRAUER et al., 2002; KATIĆ et al., 2006). The advantages of optimal pH value for alfalfa growing are evident in its easier rooting and faster plant growth, intensified nodulation and nitrogen fixation, reduced toxicity of Mn, Fe and Al and increased availability of nutrients, such as P, K and Mo (STEVOVIĆ et al., 2004).

Growing of alfalfa on acid soils is often limited by high Al and Mn concentrations and P deficit, which causes changes in soil chemical properties and availability level of some nutrients (SU and EVANS, 1996; DALL'S et al., 1996; MA et al., 2001).

To reduce soil acidity, liming is practiced i.e. the application of lime and other lime materials that provide calcium for the plant, increase available phosphorus content and decrease toxic matter and heavy metals content in the soil (STEVANOVIĆ et al., 1995; ROSELLINI et al., 2003).

According to GREWAL and WILLIAMS (2003), lime application increases alfalfa forage yield, root growth, nodulation of nodular bacteria, leaf-stem ratio and crude protein content. Liming, on the other hand, reduces content of Al, Mn and Fe in alfalfa shoots and raises content of Ca, P and Zn.

Considering large areas of pseudogley soils, especially in west and north-west Serbia and stock breeders' needs for alfalfa as quality feed, the aim of our investigations was to make provisions for growing alfalfa on those soils and utilize

it as long as possible, and all this to achieve by soil amelioration – liming and selection of tolerant alfalfa cultivars.

MATERIALS AND METHODS

To make growing of alfalfa possible on acid soils and study effects of liming application on changes in pseudogley soil agrochemical properties, a field experiment was set up in 2004 on the property of Agricultural secondary school in Kraljevo.

The experimental design was a randomized complete block system with six replicates. The size of a basic plot was $10m^2$ (5m x 2m). The investigations comprised the variants as follows (Fig. 1):

1. control – without lime application;
2. 3 t/ha of lime application.

Fig. 1. – The experimental area

Tillage was done in autumn at 25 cm depth. Along with tillage, 300 kg/ha of NPK 15:15:15 was applied to the soil.

The lime applied in the experiment contained: $CaCO_3$ (98.5%), $MgCO_3$ (1%), calculated CaO (55.3%), calculated MgO (0.5%), Fe_2O_3 (0.04%), Al_2O_3 (0.06%), Na_2O (0.24%), MnO (0.005%), S (0.011%) and Pb, Cd and Cr in traces.

Together with pre-sowing preparation of soil, the entire amount of lime was applied, three weeks prior to sowing. Experimental plot was hand sown with alfalfa variety "NS Mediana" at 1-2 cm depth on April 6, 2004.

Soil samples for determining the most important agrochemical properties were taken from the horizon of 0-30 cm depth right before lime application i.e. the experiment set up, and two years later soil sampling was done from a control and a variant where lime was applied. Soil chemical properties were determined by the JPDZ standard methods (1971).

In the first study year (2004) there were two cuts, and in the second (2005) there were four. Cutting was done at the stage of initial or full flowering, depending of the year and cut.

RESULTS AND DISCUSSION

Pseudogley soils of the Čačak-Kraljevo valley are characterized by low productivity, which is a consequence of more or less unfavorable physical and chemical properties. Total depth of those soils is high (200 cm), however, the depth of physiologically active profile where the main part of the root system develops is low (40 cm). Soil texture is characterized by high content of silt fraction in the surface horizon (Ah) and high content of clay fraction in a deeper horizon (Btg). Chemical properties are also more or less unfavorable and rather non-uniform (DUGALIĆ, 1998).

Pseudogley agrochemical properties prior to the experiment and after performed liming are presented in Tab. 1.

The results of soil agrochemical analyses prior to the experiment set up (Tab. 1) indicate that soil is of acid reaction (pH in H_2O is 5.02% and in nKCl – 4.19, respectively) in the 0-30 cm depth zone.

Table 1. – Pseudogley agrochemical properties prior to experiment and after liming

Depth (cm)	pH		Humus	Total N	C/N	Available (Al–method)	
						P_2O_5	K_2O
	H_2O	nKCl	(%)			mg/100 g	
0–30cm Without liming	5.02	4.19	2.83	0.188	8.7:1	6.2	6.7
0–30 cm With liming	5.62	5.00	2.29	0.161	8.2:1	19.1	8.6

According to humus content (2.83%), the analyzed soil belongs to the group of medium humose. Total nitrogen content in soil arable layer is proportionate to humus per cent (0.188%). Concerning contents of available phosphorus (6.2 mg/100 g) and potassium 6.7 mg/100 g), the analyzed soil is poorly supplied with those nutrients. The cause of such poor supply of phosphorus mobile forms is to be found in the fact that phosphoric acid (i.e. phosphate ions) released during organic matter mineralization, as well as applied to a soil by mineral phosphate fertilizers, bonds with Fe, Al and Mn ions into hard-soluble phosphates of those metals and thus becomes immobile, as evidenced by a volume of results reported in many domestic and foreign papers (STEVANOVIĆ, 1995; VON UEXKULL and MUTERT, 1995; DUGALIĆ, 1998; VOIGHT and STALEY, 2004).

In soil adsorption complex there prevail hydrogen ions, while base saturation level is slightly higher than 67%. The sums of exchangeable-adsorbed base cations (S-values) and cations exchange capacity (T-values) are pretty low (Tab. 2) and are characteristic of pseudogley soils, which is one of their greatest disadvantages.

Table 2. – Soil adsorption complex prior to experiment and after liming

Depth (cm)	H		S	T	V	Mobile Al
	Y_1 (ml)	me/100g	me/100g	me/100g	(%)	mg/100 g
0–30 cm Without liming	14.0	5.0	10.5	15.5	67.7	0.5
0–30 cm With liming	7.5	2.7	11.6	14.3	81.1	0.2

Content of mobile Al-ions in humus horizon of the analyzed soil is 0.5 mg/100 g, while raised content of other cations: Fe, Mn, Zn and Cu, apart from H and Al ions, is noticeable (Tab. 3) in exchangeable acidity.

Table 3. – Available microelements (DPTA) prior to experiment and after liming

Depth (cm)	Fe	Mn	Zn	Cu	B
			mg/kg		
0–30 cm Without liming	240	46	1.2	2.0	0.4
0–30 cm With liming	151	40	0.7	1.7	0.5

The application of only three tons of lime per hectare reduced acidity by 0.6 pH units in H_2O and by 0.8 pH units in nKCl. The applied lime rates represented ameliorative fertilization in character, while changes in PH values, although minimal, are a positive sign of halting further soil acidification, which was manifested by increased alfalfa yield.

Lime application reduced humus content compared to a variant without liming, which can be explained by intensified humus mineralization and decrease of its non-mineralized residue in conditions of more intensive chemical and microbiological processes in soil under the influence of applied calcium. Similar to humus content decrease, reduction of total nitrogen content is evident compared to control.

The increase of soil pH and decrease of soil acidity, respectively, resulted in increase of available forms of phosphorus and potassium content. The increase was found in all variants of the experiment where lime fertilizer was applied, whereas changes in potassium content were not that significant. However, it is noticeable that lime caused the release of a portion of potassium and slight increase of its content in the soil. Also, lime produced increase in the level of soil adsorption complex, primarily of base saturation percentage (from 67.7 to 81.1%).

Apart from pH value increase, lime application reduced concentration of Al and Mn and Fe toxic ions to a relatively tolerant level, thus increasing the absorption of needed macronutrients and microbiological activity, which contributes to better root system development and alfalfa plants' development, respectively, as well as higher forage yield.

Under conditions of increased content and mobility of toxic forms of Mn and Fe ions plants are found in the so-called "stressful conditions". High concentration primarily of Al, Fe and Mn causes disorders in absorption, transport and reutilization of Ca, Mg, P and K via water absorption and enzymatic activity in plant root (FOY et al., 1988). Hence, the application of lime materials is a necessary measure for their concentration reduction at least to the level that does not affect grown plants.

Effects of liming on alfalfa yield

The results of investigations indicate that alfalfa responds to lime application by a significant yield increase (Tab. 4). Alfalfa reaction to lime application was stronger in the second year of plant's life compared to the first. In the first year (sowing year) 28.5 t/ha of forage was produced and 8.2 t/ha of hay, respectively, whereas in control variant (without liming) the achieved forage yield was 19.7 t/ha and that of hay 5.7 t/ha. In the second year, compared to the first, differences in yield were more prominent. Namely, in the variant with lime application the produced forage yield was 71.4 t/ha and hay yield 16.3 t/ha, respectively, while in control variant yield was statistically significantly lower: 8.5 t/ha of forage and 2.2 t/ha of hay, respectively.

Lime application significantly increases yield of green manure, hay, stem height, number and length of internodes in alfalfa grown on pseudogley soil. According to GREWAL and WILLIAMS (2003), lime application increases alfalfa root growth, nodulation of nodular bacteria, leaf-stem ratio, yield, crude protein content. On the other hand, liming reduces content of Al, Mn and Fe in alfalfa shoots, while increasing content of Ca, P and Zn.

Table 4. – Effects of lime application on alfalfa yield

Variant	2004		2005	
	Green manure (t/ha)	Hay (t/ha)	Green manure (t/ha)	Hay (t/ha)
Control	19.7	5.7	8.5	2.2
3 t/ha of lime	28.5	8.2	71.4	16.3

Positive effects of lime application on alfalfa yield increase on acid soils are also reported by JEREMIĆ (1995). He points out that hydrated lime application at the rate of 200 kg/ha increased statistically significantly alfalfa hay yield by 29% in the first, 112% in the second and 120% in the third year, amounting to 8-13 t/ha in absolute values. Similar results are reported by STEVOVIĆ et al. (2004).

REFERENCES

BRAUER, D., D. RITCHEY and D. BELESKY (2002): Effect of lime and calcium on root development and nodulation of clovers. Crop Sci. 42: 1640–1646.

DALL'S AGNOL, M., BOUTON, J. H., PARROTT, W. A. (1996): Screening methods to develop alfalfa populations tolerant to acid, aluminium toxic soils. Crop Sci., 36: 64–70.

DUGALIĆ, G. (1998): Karakteristike kraljevačkog pseudogleja i iznalaženje mogućnosti za povećanje njegove produktivne sposobnosti. Doktorska disertacija. Poljoprivredni fakultet, Zemun.

FOY, C. D. (1988): Plant adaptation to acid, aluminium toxicity soil. Comm. Sci. Plant Anal., 19, 959–978.

GREWAL, H. S. and WILLIAMS, R. (2003): Liming and Cultivar Affect Root Growth, Nodulation, Leaf to Stem Ratio, Herbage Yield and Elemental Composition of Alfalfa on an Acid Soil. Journal of Plant Nutrition, 26, 8, 1683–1696.

HAUPTVOGEL, R. (2003): Strategy of Lucerne Breeding and in Abiotic Stress. Chech J. Genet. Plant Breed., 39 (special Issue), 163–167.

JEREMIĆ (1995): Kalcifikacija kiselih zemljišta kao faktor unapređenja gajenja lucerke. Savetovanje „Popravka kiselih zemljišta Srbije primenom krečnog đubriva „Njival Ca", Zbornik radova, Paraćin, str. 166–172

KATIĆ, S., VASILJEVIĆ, S., MILIĆ, D., LAZAREVIĆ, B., DUGALIĆ, G. (2006): Mogućnost gajenja lucerke i crvene deteline na pseudogleju uz primenu krečnjaka i rizobiuma. Zbornik radova, Sveska 42, str. 31–39. Naučni Institut za ratarstvo i povrtarstvo Novi Sad.

LANYON, L. E. and GRIFFITH, W. K. (1988): Nutrition and Fertilizer Use. Alfalfa and Alfalfa Improvement, ed. Hanson, A. A., Madison Wisconsin, USA, 334–373.

MA, J. F., RYAN, P. R., DELHAIZE, E. (2001): Aluminium tolerance in plants and the complexing role of organic acids. Trends Plant Sci., 6: 273–278.

RENGEL, Z. (2002). Role of pH in Avaliability of Ions in Soil. In: Handbook of Plant Growth. pH as the Master Variable. New York, Basel: Marcel Dekker, Inc.: 323–350.

ROSELLINI, D., BARONE, P., BOUTON, J., LA FAYETTE, P., SLEDGE, M., VERONESI, F. and W. PARROTT (2003): Alfalfa for Acid Soils: A Biotech Approach. Chech J. Genet. Plant Breed., 39 (special Issue), 168–172.

STEVANOVIĆ, D., JAKOVLJEVIĆ, M., MARTINOVIĆ, LJ. (1995): Rešavanje problema kiselih zemljišta Srbije–preduslov povećanja proizvodnje hrane i zaštite zemljišta. Savetovanje „Popravka kiselih zemljišta Srbije primenom krečnog đubriva „Njival Ca", Zbornik radova, Paraćin, str. 7–21.

STEVOVIĆ, V., ĐUKIĆ, D., ĐUROVIĆ, D., ĐALOVIĆ, I. (2004): Uticaj kalcifikacije na prinos i kvalitet krme lucerke i crvene deteline. Acta Agriculturae Serbica, IX, 17, 295–301.

SU, C. and EWANS, L. J. (1996): Soil solution chemistry and alfalfa response to CaCO3 and MgCO3 on an acid Gleysol. Canadian Journal of Soil Science 76, 41–47.

VOIGT, P. W., T. E. STALEY (2004): Selection for Aluminium and Acid – Soil Resistance in White Clover. Crop Sci. 44: 38–48.

VON UEXKULL, H. R. MUTERT, E. (1995): Global extent, development and economic impact of acid soils. In: Date R. A., Grundon, N. J., Rayment, G. E. Probert, M. E. (eds.): Plant–soil interaction at low pH: Principles andManagement. Kluwer Academic Publ., Dordrecht: 5–19

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UTICAJ KALCIFIKACIJE NA PROMENE AGROHEMIJSKIH OSOBINA PSEUDOGLEJA I PRINOS LUCERKE

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I z v o d

Loše agrofizičke, a naročito agrohemijske osobine pseudoglejnih zemljišta okoline Kraljeva su ograničavajući faktor za gajenje lucerke. Cilj ovih istraživanja je bio da se melirativnom đubrenjem zemljišta-primenom kalcifikacije poprave agrohemijska svojstva pseudogleja i povisi prinos zelene krme i sena lucerke.

Rezultati ovih istraživanja pokazuju da se umerenom kalcifikacijom od 3 t/ha kreča moze značajno smanjiti kiselost za 0,6 pH jedinica u H_2O, i za 0,81 pH jedinicu u nKCl. Smanjenjem kiselosti povećana je pristupačnost fosfora (sa 6,2 mg/100g zemljišta, kontrola, na 19,1 mg/100g zemljista varijanta sa primenom kreča) i povećan stepen zasićenosti zemljišta bazama u oraničnom horizontu od 0-30cm. Izvedena kalcifikacija pojačala je mineralizaciju organske materije što je uticalo na smanjenje sadržaja humusa, a takođe smanjen je i sadzaj mobilnog Al i Fe u odnosu na kontrolu varijantu.

Popravljena agrohemijska svojstva pseudogleja doprinela su povećanju prinosa krme i sena lucerke. U prvoj godini na kontrolnoj varijanti ostvaren je prinos krme od 19,7 t/ha, odnosno 5,7 t/ha sena, dok na varijanti sa primenom kreča 28,5 t/ha krme, odnosno 8,2 t/ha sena. To povecanje prinosa jos je vise bilo izraženo u drugoj godini iskorišćavanja lucerke (kontrola 8,5 t/ha krme, odnosno 2,2 t/ha sena, a varijanta sa krečom 71,4 t/ha krme, odnosno 16,3 t/ha sena).

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